

PATENT APPLICATION TRANSMITTAL LETTER

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TO THE COMMISSIONER OF PATENTS AND TRADEMARKS:

Transmitted herewith for filing is the patent application of:

Hanan Gothait

for SYSTEM AND METHOD FOR THREE DIMENSIONAL MODEL PRINTING

Enclosed are:

- (X) 24 pages of specification and claims.
- (X) Abstract
- (X) 8 sheet(s) of Informal Drawings.
- (X) Declaration and Power of Attorney
- (X) Statement to establish small entity status of  
Small Business Concern under 37 CFR 1.9 and 1.27.
- ( ) Information Disclosure Statement
- (X) Assignment and Assignment Recordation
- ( ) Preliminary Amendment
- ( ) A check in the amount of \$\_\_\_\_\_ to cover the filing fee.
- (X) Any filing fees or presentation of extra claim  
fees may be charged to Deposit Account No. 05-0649  
(Eitan, Pearl, Latzer & Cohen-Zedek)

CLAIMS AS FILED

SMALL ENTITY

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BASIC FEE				\$380.00			\$760.00
TOTAL CLAIMS	29-20	9	x\$ 9	\$ 81.00		x\$ 18=	\$
INDEP. CLAIMS	3-3		x\$ 39	\$		x\$ 78=	\$
MULTIPLE DEP. CLAIM PRESENT			x\$130=	\$		x\$260=	\$
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Respectfully submitted,



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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application ) PATENT APPLICATION  
Inventor(s): Hanan GOTHAIT )  
Docket No.: P-2070-US )  
Title: SYSTEM AND METHOD FOR THREE DIMENSIONAL  
MODEL PRINTING

VERIFIED STATEMENT CLAIMING SMALL ENTITY STATUS  
37 C.F.R. § 1.9(f) AND 1.27(c) - SMALL BUSINESS CONCERN

I hereby declare that I am:  
           The owner of the small business concern identified below.

☒ An official of the small business concern empowered to act on behalf of  
the concern identified below.

Name: **OBJET GEOMETRIES LTD.**  
Address: The Kiryat Wicsmann Science Park, Bldg. No. 16, P.O.B. 2496,  
Rehovot 76124, Israel

I hereby declare that the above identified small business concern qualifies as a small  
business concern as defined in 13 C.F.R. § 121.12, and reproduced in 37  
C.F.R. § 1.9(f), for purposes of paying reduced fees under Section 41(a) and (b) of  
Title 35 U.S.C. in that the number of employees of the concern, including those of its  
affiliates, does not exceed 500 persons. For purposes of this statement, (1) the  
number of employees of the business concern is the average over the previous fiscal  
year of the concern of the persons employed on a full-time, part-time or temporary  
basis during each of the pay periods of the fiscal year, and (2) concerns are affiliates  
of each other when either, directly or indirectly, one concern controls or has the  
power to control the other, or a third-party or parties controls or has the power to  
control both.

I hereby declare that rights under contract or law have been conveyed to and remain  
with the small business concern identified below with regard to the invention entitled:

**APPARATUS AND METHOD FOR THREE DIMENSIONAL MODEL PRINTING**

by inventor(s): Hanan GOTHAIT

described in:

☒ the Specification filed herewith  
           Application SC/Serial No.            filed

If the rights held by the above-identified small business concern are not exclusive, each individual, concern or organization having rights to the invention is listed below and no rights to the invention are held by any person, other than the inventor, who could not qualify as a small business concern under 37 C.F.R. § 1.9(d) or by any concern which would not qualify as a small business concern under 37 C.F.R. § 1.9(d) or a nonprofit organization under 37 C.F.R. § 1.9(e).

NAME: \_\_\_\_\_

ADDRESS: \_\_\_\_\_

☐ Individual  
Organization

☐ Small Business Concern

☐ Nonprofit

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small business entity is no longer appropriate. (37 C.F.R. § 1.28(b)).

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

Name of Person Signing: X Hanan Gathail

Title of Person Signing: X Managing Director

Address of Person Signing: X 3 Paldi St. RENOVT ISRAEL

Signature: X [Signature]

Date: X 5. OCT. 1999

\* Note: Separate verified statements are required from each named person, concern or organization having rights to the invention averring to their status as small entities. (37 C.F.R. § 1.27).

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**Title 37, Code of Federal Regulations, § 1.9(c-f)**

(c) An independent inventor as used in this chapter means any inventor who (1) has not assigned, granted, conveyed, or licensed, and (2) is under no obligation under contract or law to assign, grant, convey, or license, any rights in the invention to any person who could not likewise be classified as an independent inventor if that person had made the invention, or to any concern which would not qualify as a small business concern or a nonprofit organization under this section.

*which would not qualify as a small business concern or a nonprofit organization under this section. For the purpose of this section concerns are affiliates of each other when either, directly or indirectly, one concern controls or has the power to control the other, or a third party or parties controls or has the power to control both. The number of employees of the business concern is the average over the fiscal year of the persons of the fiscal year. Employees are those persons employed on a full-time, part-time or temporary basis during the previous fiscal year of the concern.*

(d) A small business concern as used in this chapter means any business concern as defined by the Small Business Administration in 13 CFR 121.12. For the convenience of the users of these regulations, that definition states:

(e) A nonprofit organization as used in this chapter means (1) a university or other institution of higher education located in any country; (2) an organization of the type described in section 501(c)(3) of the Internal Revenue Code of 1954 (26 U.S.C. 501(c)(3)) and exempt from taxation under section 501(a) of the Internal Revenue Code (26 U.S.C. 501(a)); (3) any nonprofit scientific or educational organization qualified under a nonprofit organization statute of a state of this country (35 U.S.C. 201(i)); or (4) any nonprofit organization located in a foreign country which would qualify as a nonprofit organization under paragraphs (c)(2) or (3) of this section if it were located in this country.

**121.12 Small business for paying reduced patent fees.** (a) Pursuant to Pub. L. 97-241, a small business concern for purposes of paying reduced fees under 35 U.S. Code 41 (a) and (b) to the Patent and Trademark Office means any business concern (1) whose number of employees, including those of its affiliates, does not exceed 500 persons and (2) which has not assigned, granted, conveyed, or licensed, and is under no obligation under contract or law to assign, grant, convey or license, any rights in the invention to any person who could not be classified as an independent inventor if that person had made the invention, or to any concern

(f) A small entity as used in this chapter means an independent inventor, a small business concern or a nonprofit organization.

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# SYSTEM AND METHOD FOR THREE DIMENSIONAL MODEL PRINTING

## FIELD OF THE INVENTION

This present invention relates to three-dimensional (3-D) modeling in general and to a system and a method for 3-D printing of complex structures in particular.

## BACKGROUND OF THE INVENTION

3-D printing, which works by building parts in layers, is a process used for the building up of 3-D models. 3-D printing is relatively speedy and flexible allowing for the production of prototype parts and tooling directly from a CAD model, for example.

Using 3-D printing enables the manufacturer to obtain a full 3-D model of any proposed product before tooling thereby possibly substantially reducing the cost of tooling and leading to a better synchronization between design and manufacturing. A lower product cost and improved product quality can also be obtained.

Various systems have been developed for computerized 3-D printing. Known systems include a system developed by 3-D Systems Inc. of California, USA, which operates on the basis of stereo-lithography wherein a focused ultra-violet laser is scanned over the top of a bath of photopolymerizable liquid polymer plastic material. The surface of the bath is polymerized on contact with the UV laser creating a solid plastic layer at or just below the surface

US Patent No. 5,387,380 to Cima et al. describes a technique for providing layered parts by depositing a layer of powder material and then depositing a binder material in selected regions to produce a layer of bonded

powder material at the selected regions. These steps are repeated for successive layers to form a desired component. Following heat treatment, unbound powder is removed, leaving the fabricated part.

US Patent No. 5,287,435 to Cohen et al describes apparatus for producing  
5 3-D models which includes apparatus for depositing layer-by-layer, a photopolymer material in a selectable configuration and apparatus for curing each layer prior to deposition of the succeeding layer.

A disadvantage of these systems is the difficulty of printing 3-D models having a complex structure such as a tea cup, for example (shown in Fig. 2).

10 In US Patent Application No: 09/259323 to the Assignees of the present application, and incorporated herein by reference, there is described an apparatus and a method for 3-D model printing. U.S. Patent Application 09/259323 describes apparatus including a printing head having a plurality of nozzles, a  
15 dispenser connected to the printing head for selectively dispensing interface material in layers and curing means for optionally curing each of the layers deposited. The depth of each deposited layer is controllable by selectively adjusting the output from each of the plurality of nozzles.

## SUMMARY OF THE INVENTION

The present invention provides a 3-D printing system and a method for printing complex 3-D models by utilizing at least two printing heads which eject interface material. By using interface material having different hardness (or modulus of elasticity) and mixing the interface material from each of the printing heads, the hardness of the layers of material forming the 3-D model can be controlled. The layers forming the construction layers of the model are formed from interface material having a different (harder) modulus of elasticity from the layers forming the release layers, thereby allowing for the forming complex shapes.

There is thus provided, in accordance with a preferred embodiment of the present invention, a method for three-dimensional printing of a three-dimensional model. The method includes:

- dispensing a first interface material from a printing head;
- dispensing at least a second interface material from the printing head; and
- combining the first and second interface material in pre determined proportions to produce construction layers for forming the three-dimensional model.

Furthermore, in accordance with a preferred embodiment of the present invention, the printing head includes first and second printing heads. The first interface material and second interface material are dispensed from the first and second printing heads, respectively.

Furthermore, in accordance with a preferred embodiment of the present invention, the method further includes the step of curing the first interface material for a first period of time and at a first radiation wavelength to obtain a first modulus





head for dispensing at least first and second interface materials therefrom respectively, and control means connected to the printing head for combining at the first and second interface materials in pre-determined proportions to produce forming the three-dimensional model.

5 Furthermore, in accordance with a preferred embodiment of the present invention, the system further includes curing means for optionally curing the layers. The curing means includes a first curing means for curing the first interface material for a first period of time and at a first radiation wavelength to obtain a first modulus of elasticity; and a second curing means for curing the second interface  
10 material for a second period of time and at a second radiation wavelength to obtain a second modulus of elasticity.

The printing head includes first and second printing heads wherein the first interface material and second interface material are dispensed from the first and second printing heads, respectively.

15 Furthermore, in accordance with a preferred embodiment of the present invention, the layers comprise first construction layers and second release layers. The first construction layers and the second release layers have differing proportions of the first and the second interface materials, respectively, and different modulus of elasticity.

20 Furthermore, in accordance with a preferred embodiment of the present invention, the system further includes positioning apparatus coupled to the control means for selectively positioning the first and second printing heads by commands from the control means.

In addition, there is provided, in accordance with a preferred embodiment  
25 of the present invention, a system for three-dimensional four-color printing of a

three-dimensional model, which includes at least one printing head, having a plurality of nozzles, a plurality of dispensers connected to the at least one printing head for dispensing a plurality of interface materials and control means connected to the at least one printing head for combining the plurality of interface materials in  
5 pre-determined proportions to produce layers having different colors for forming the three-dimensional model.

Furthermore, in accordance with a preferred embodiment of the present invention, the printing head includes a plurality of printing heads and wherein each of the plurality of interface materials are dispensed from a different one of each of  
10 the plurality of printing heads, respectively.

Furthermore, in accordance with a preferred embodiment of the present invention, the system further includes curing means for optionally curing the layers. The curing means includes at least first curing means for curing at least one of the plurality of interface materials for a first period of time and at a first radiation  
15 wavelength to obtain a first modulus of elasticity. The system further includes a dispenser for dispensing transparent material.

Furthermore, in accordance with a preferred embodiment of the present invention, the layers have different modulus of elasticity. The layers are a photopolymer material curable by the application of any one of a group including  
20 ultra violet radiation, infra red radiation and E-beam.

## BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be understood and appreciated more fully from the following detailed description taken in conjunction with the appended drawings in which:

5           Fig. 1 is a schematic illustration of an embodiment of a 3-D printing system, described in US Patent Application No: 09/259,323, assigned to the Assignees of the present application;

          Fig. 2 is an elevational view of an 3-D object printable by the printing system of Fig.3;

10          Fig. 3 is a schematic illustration of a 3-D printing system, constructed and operative in accordance with a preferred embodiment of the present invention;

          Fig. 4 is an enlarged detail of the 3-D object of Fig. 2;

          Fig. 5 is flow chart illustrating the build-up of the 3-D object of Fig. 2;

          Figs 6A, 6B, 6C and 6D are schematic elevational illustrations of examples  
15 of 3-D objects constructed by the 3-D printing system of Fig. 3;

          Fig. 6E is an enlarged detail of adjacent 'release blocks';

          Fig. 7 is a schematic illustration of a printing head for use with the printing system of Fig. 3; and

          Fig. 8 is a schematic illustration of part of an alternative embodiment of  
20 part of a 3-D printing system.

### List of Definitions

The following definitions are used in this Application:

block - any size or shape of interface material deposited by at least one nozzle of a printing head;

5 pass - a plurality of blocks deposited in a single pass of a printing head;

layer - a plurality of passes by a printing head

model layer (or component) - a layer of interface material constituting the 3-D model;

10 support layer (or component) - a layer of interface material for supporting the 3-D model layer and not constituting the 3-D model;

release layer (or component) - a layer of interface material for separating the 3-D model layer from components, such as the support layer, not constituting the 3-D model.

15 The terms hardness and softness are used as relative terms to indicate the differences in modulus of elasticity between interface materials. The hardness of a material may be described by reference to its modulus of elasticity, which may be defined as: "The ratio of stress to its corresponding strain under given conditions of load, for materials that deform elastically, according to Hooke's law".

## DETAILED DESCRIPTION OF THE PRESENT INVENTION

Reference is made to Fig. 1, which is a schematic illustration of the 3-D printing system, generally designated 10, described in US Patent Application No: 09/259,323, assigned to the Assignees of the present application and incorporated  
5 herein by reference.

The 3-D printing system 10 includes a printing head 12 having a plurality of ink-jet nozzles 14, through which interface material 16 is jetted and a curing unit 18 for curing the interface material 16 to form the 3-D component, referenced 20, being designed. The interface material 16 is preferably a photopolymer, containing  
10 ultra violet (UV) or infra red (IR) curable material. For example, material based on reactive acrylates is suitable for UV curing or hardening by the application of UV radiation from curing unit 18. The 3-D component 20 is build up in layers, the depth of each layer being controllable by selectively adjusting the output from each of the plurality of ink-jet nozzles 14.

15 The 3-D printing system 10 further includes a dispenser 22, a process controller 24 and a Computer Aided Design (CAD) system 26. The process controller 24 is coupled to CAD system 26, curing unit 18 and printing head 12.

The dispenser 22, which contains interface material 16, is suitably connected to printing head 12. The 3-D component 20 is formed on a support  
20 surface 28, which can be optionally positioned in the Z- and Y- axes by positioning apparatus 30.

Reference is now made to Fig. 2 which is an elevational view of a tea cup, generally referenced 50. In order to print this 3-D model using ink-jet type printing heads of Fig. 1, two problems need to be overcome. Firstly, since the printing  
25 head 12 prints or deposits interface material in horizontal layers, the model layers

52 of the tea cup 50 need to be supported externally, such as under the handle 52 (indicated by the stepped support 54), and secondly, an internal void, referenced 50, needs to be formed during printing.

Reference is now also made to Fig. 3, which is a schematic illustration of a 3-D printing system generally designated 100, constructed and operative in accordance with a preferred embodiment of the present invention, for forming the 3-D component, referenced 102, being designed. Fig. 3 is similar to Fig. 1 and utilizes similar components. These components have been similarly designated and will not be described further.

The 3-D printing system 100 includes a plurality of printing heads, generally referenced 104 and individually referenced 104a, 104b, etc. connected to corresponding interface material dispensers 106a, 106b, etc. containing interface material, correspondingly referenced 108a, 108b, etc.

The printing heads 104 each preferably have a plurality of ink-jet type nozzles 105, through which interface material 108a, 108b is jetted. The interface material 108a, 108b is preferably a photopolymer, containing ultra violet (UV) curable material suitable for UV curing or hardening by the application of UV radiation from curing unit 18. The 3-D printing system 100 further includes a dispenser 106a, 106b, a controller 110 and a Computer Aided Design (CAD) system 26 and optionally positioning apparatus 30. The controller 110 is coupled to CAD system 26, curing unit 18, positioning apparatus 30, each of the printing heads 104, and dispensers (106a-106d).

The Applicants have realized that by combining or mixing material from at least two printing heads, wherein each printing head dispenses interface material having a different hardness, it is possible to adjust and control the hardness of the

material forming the 3-D object being produced. Thus, by controlled mixing of the interface material being output from each of the printing heads, different parts of the 3-D object 102 having different modulus of elasticity can be produced utilizing these printing heads.

5 Thus, in the example of the tea cup 50 (Fig. 2), the support layers 54 may be constituted from mix proportions similar to (or alternatively different from) the constructed model layer 52, such as the handle 53, since the support layer 54 is separated from the model layer 52 by a release layer, referenced 58, which is generally softer than the model layer 52.

10 The release layer 58, between the support layer 54 and model layer 52 can be constituted by mixing the proportions of the interface materials so that the mix for the release layer 58 is softer than the constructed model layer 52. Thus, the support layer can be easily separated from the 3-D model to leave the desired completed product. Similarly, the internal void 56 can be formed from a softer mix  
15 than the cup wall 60.

The terms hardness and softness are used as relative terms to indicate the differences in modulus of elasticity between the interface materials 108a and 108b in the respective interface material dispensers 108a and 108b.

20 Modulus of elasticity may be measured in mega Pascal units. For the purposes of example only and without any limiting the present application, the interface material 108a preferably has a modulus of elasticity of 1000 mega Pascal while softer interface material 108b preferably has a modulus of elasticity of less than 1 mega Pascal. As described in the aforementioned US Patent Application No: 09/269323, the 3-D model is build up in layers. The 3-D model tea cup 50 can

be formed in layers, utilizing two printing heads, as will now be described with reference to Fig. 4 which is an enlarged detail of part of the tea cup 50 of Fig. 2.

Tea cup 50 includes a base 62 as well as the generally cylindrical wall 60. The construction of the cup 50 is schematically illustrated by several layers, 5 referenced L1, L2, ..... L9, etc. The support layers 54 are referenced L1s, L2s, etc., the release component 58 of the layer are referenced L1r, L2r, etc and the model layers are L1m, L2m, etc. The layers shown are not to scale and it will be appreciated that since a single jetted deposited layer is approximately 10 $\mu$ , the thickness of the layers shown (L1, L2 etc) may consist of several deposited layers 10 and be formed from several passes of the printing heads 104.

Reference is now also made to Fig. 5 which is flow chart illustrating the build-up of the 3-D object 102 using two printing heads 104, each of which preferably have a plurality of nozzles 105. A file of the model to be produced is downloaded to the CAD system 26 (step 202) allowing the operator to view the 15 model and control the operational procedure.

The operator selects those variables (step 204) which define the finished product. These variables include the desired resolution of the jet head, the desired spacing between consecutive ink-dot lines and the number (h) of layers to be used in building up the model. The number of steps (i) through which the printing heads 20 104 are displaced (in the x-y axes) to print a single layer and the number of vertical steps (j), in the z-axis, to print the model are calculated. These steps are described in U.S. Patent Application 09/259323.

The printing heads 104a, 104b are positioned at the start position (axis line 64) for the first layer L1 (step 206) and the mix formulation for the type of layer at 25 this position determined (step 208).



In the example of Fig. 4, position 64 is a support layer (L1s) and thus, the mix is formulated so as to be of sufficient consistency for supporting the plurality of layers (L2, L3, etc) above it. For example, the support layers (L1s, L2s, etc.) may be constituted in the proportion of 80% of interface material 108a and 20% of interface material 108b. In this example, the model layers, such as base 62 and walls 64, may be constituted in the proportion of 90-100% of interface material 108a and up to 10% of interface material 108b. The release layers generally consist of a higher proportion of softer interface material 108b and may be constituted, for example, in the proportion of 5% of interface material 108a and 95% of interface material 108b

The support layer L1s is formed by simultaneously ejecting interface material from both printing heads 104a and 104b in the determined proportions (step 210). As the printing heads move from left to right, the support layer changes to a release layer (arrow 66). The mix formulation is changed to that required for the release layer (L1r) (query box 212) and the softer release layer is deposited (repeating steps 208-212). If the type of layer is the same, the same mix is deposited (step 214).

Steps 208 - 214 may be repeated several times so that the single layer (L1) is build up from several passes of the printing heads 104a, 104b (step 216).

After completing the layer (L1), the printing heads 104a, 104b are moved back to the start position for the next layer (L2) and repositioned in the vertical-axis (64) above the first layer (step 218). Since the thickness of a layer is approximately  $10\mu$ , it is not essential to reposition the printing head relative to the model after every pass, and this step may be deferred at the discretion of the operator.

The mix formulation for this position is determined (repeat step 208). In this case, since it is a support layer, the mix is the same as in layer L1. However, it will be appreciated that the mix formulation may vary from support layer to support layer and need not be the same each time.

5 The support layer L2s is formed by simultaneously ejecting interface material from both printing heads 104a and 104b in the determined proportions (similar to step 210). As the printing heads move from left to right, the support layer changes to a release layer (arrow 68). The mix formulation is changed to that required for the release layer (L2r) (similar to step 208) and the softer release  
10 layer is deposited (similar to step 210). As the printing heads move from left to right, the release layer changes to the model layer (along curve 70). The mix formulation is changed to that required for the model layer (L2m) and the model layer is deposited as previously described with respect to the lower layers.

Since the change from support (L2s) to release layer (L2r) to model layer  
15 (L2m) does not occur at the identical point on the vertical axis along the whole horizontal length of this layer (L2) in contrast to layer L1, the repetition of steps 208 - 218 are not exactly identical for each of the passes making up the layer. In practice since each pass is approximately 10μ, the change from one type of mix to another is a smooth transition during each pass.

20 After completing the layer (L2), the printing heads 104a, 104b are moved back to the start position for the next layer (L3) and repositioned in the vertical-axis (64) above the first layer (repeat step 218).

The deposition of layer L3 is similar to that described for layer L2 with the following difference: As the printing heads 104a, 104b continue their pass, there is  
25 an additional transition, from model layer (L3m) to release layer (L3r). In this case,

after the model layer L3m has been deposited, the mix formulation is changed to that required for the release layer (L2r) (repeat step 208) and sufficient of the release layer (69) is deposited (repeat step 210) adjacent to the model layer (L3m) so as to provide a break between the model layer and the release layer.

6 After the release layer 69 has been deposited, there is a further transition, from release layer (L3r) to a support layer (L3s). The modulus of elasticity of this support layer (L3s) may be similar to the modulus of elasticity of the previously laid support layer or of any other layer, such as the model (L3m) layer, which is harder than the release layer (L3r).

10 Curing is preferably carried out after the deposition of each layer. However, alternatively, curing may be optionally deferred so that curing occurs after the deposition of more than one layer.

Reference is now made to Figs. 6A- 6D, which are schematic elevational illustrations of examples of 3-D models which illustrate the operation of the invention. Figs. 6A and 6B illustrate generally non- complex shapes. Fig. 6A is a sectional elevation of a 3-D model part 70 having model layers 72, support layers 15 74 (shown hatched) and release layers 76 (delimited by dashed lines). Fig. 6A has a generally rectangular cross-section similar to a 'mortise' with a 'tenon'-like component removed.

20 Fig. 6B is a sectional elevation of a 3-D model part 80 having model layers 82, support layers 84 (shown hatched) and release layers 86 (delimited by dashed lines). Fig. 6B has a generally "I" cross-section. In both Figs. 6A and 6B, the release layers 76 and 86, respectively, can be easily detached from the model and thus they may be formed of the interface material having the same hardness or 25 modulus of elasticity. Alternatively, adjacent release blocks, such as those

referenced 76a and 76b, may be constituted from materials having different modulus of elasticity, so that these release blocks may be separated from each other. This is particularly important for complex shapes such as those shown in Figs. 6C and 6D, to which is now made.

5 In a further embodiment of the present application, the release layer for complex shapes includes a plurality of passes, each pass comprising a plurality of 'release blocks', wherein each of the release blocks contains interface material of a different specific modulus of elasticity (or hardness).

Fig. 6C is a sectional elevation of a 3-D model part 90 having model layers 10 92, and release layers 94 (shown by dashed lines). Fig. 6D is a sectional elevation of a 3-D model part 96 having model layers 97, and release layers 98.

In contrast to the shapes of Figs 6A and 6B, the release layer 94 of Fig. 6C is not easily detached from the model 92 because of the triangular element, 15 referenced 94a. Similarly, the release layer 98 of Fig. 6D is not easily detached from the model 96 because of the double triangular element, referenced 98a.

In order to separate the release layers formed within complex shapes, the release layers are formed from a plurality of 'release blocks'. Thus, in the example of Fig. 6D, release layers 98a is constituted from a plurality of adjacent blocks, 20 referenced B1, B2, B3, etc. Each of the release blocks contains interface material of a specific modulus of elasticity (different hardness). Thus, the release layer defined by the row comprising blocks B1-B9 is constituted from blocks which because adjacent blocks have material of different hardness allow the row to more 25 easily be detached and thus released from the model. Consequently, once this row (B1-B7) has been detached, the row above it comprising blocks B7-B16 can similarly be detached.

It will be appreciated by persons knowledgeable in the art that the release blocks are not limited to any size or shape and that a release block may itself be constituted from a plurality of smaller "sub-blocks" of different size and shape.

In an alternative embodiment, which is illustrated by reference to Fig. 6E, which is an enlarged detail of adjacent 'release blocks', a "skin release" layer 101 is formed between adjacent 'release blocks', thereby facilitating the release of adjacent blocks B3/B4. The "skin release" layer may be formed by depositing interface material of a lower elasticity than the release layer itself, while moving the printing head slightly sideways, that is by a width less than the width of the 'release block'. For example, for a release block having a width of say 50 microns, a "skin release" layer of approximately 10 microns can be formed. This "skin release" layer may be applied to any geometric block shape.

It will be appreciated that the use of blocks is not restricted to release blocks but support and model layers may also be constituted from a plurality of blocks.

It will be appreciated that the use of two or more print heads is not limited to dispensing interface material having different modulus of elasticity or hardnesses but that the print heads may also contain interface material having different colors and/or different transparencies.

Thus, in a further embodiment of the invention, 3-D printing system 100 may comprise four printing heads, each one for dispensing a different color, allowing for four-color (CMYK) printing. A further printing head may also be used for dispensing transparent interface material, for example.

In an alternative embodiment, instead of using two print heads, each dispensing interface material, which may have a different modulus of elasticity

and/or other different characteristics, such as different colors, a single print head can be adapted so as to dispense two or more interface materials.

Reference is now made to Fig. 7, which is a schematic illustration of a printing head 120. Printing head 120, which is similar to the printing heads 104 (described hereinabove with respect to Fig. 3), includes a plurality of ink-jet type nozzles 122a and 122b, through which interface material 124a and 124b, respectively, is jetted. That is, the printing head 120 is divided into two groups of ink-jet nozzles. Thus, the single printing head 120 is similar to two of the printing head 104 (Fig. 3).

10 In operation, ink-jet nozzles 122a and 122b can be activated in accordance with pre-determined control commands to dispense either or both of interfacial materials 124a and 124b, as required, to selectively mix material to achieve a material of specific modulus of elasticity.

In a further alternative embodiment, illustrated in Fig. 8, the hardness (modulus of elasticity) of the dispensed material can be controlled by regulating the curing time of the material being dispensed. Fig. 8 schematically illustrates a printing system 130 comprising inter alia a printing head 132 and two curing units 134 and 138.

The printing head 132 includes a plurality of ink-jet type nozzles, similar to those described hereinabove with respect to Fig. 3, for dispensing interface material. The curing units 134 and 136 are any suitable curing units utilizing UV radiation, for example, for curing. Each of the curing units 134 and 136 can be configured for emitting radiation of different wavelengths. By adjusting the radiation wavelength and/or the time for curing, the cured interface material will have a different modulus of elasticity.

Thus, in order to produce interface materials for the support, release and construction layers, having different modulus of elasticity, different radiation wavelengths are used. By using two curing units, each emitting radiation of a different wavelength, the hardness of the interface material is controllable. Thus, 5 by selectively curing the interface material being deposited it is possible to control the softness (hardness) of the material and hence determine the adhesiveness of the material being applied to the surface.

It will be further appreciated that the present invention is not limited by what has been described hereinabove and that numerous modifications, all of 10 which fall within the scope of the present invention, exist. Rather the scope of the invention is defined by the claims, which follow:

## CLAIMS

1. A method for three-dimensional printing of a three-dimensional model, said method comprising:
- dispensing a first interface material from a printing head;
  - 5 dispensing at least a second interface material from said printing head; and
  - combining said first and second interface material in pre-determined proportions to produce construction layers for forming the three-dimensional model.
- 10 2. The method according to claim 1, wherein said printing head includes first and second printing heads and wherein said first interface material and second interface material are dispensed from first and second printing heads, respectively.
3. The method according to claim 1, further comprising the step of:
- 15 curing said first interface material for a first period of time and at a first radiation wavelength to obtain a first modulus of elasticity.
4. The method according to claim 1, further comprising the step of:
- curing said second interface material for a second period of time and at a second radiation wavelength to obtain a second modulus of elasticity.
- 20 5. The method according to claim 1, wherein said step of combining includes the step of:



adjusting the relative proportions of said first and second interface materials, said first and second interface materials having different modulus of elasticity.

6. The method according to claim 1, further comprising the step of:  
5 combining said first and second interface material in pre-determined proportions to form a release layer, said release layer having a lower modulus of elasticity than said construction layer.

7. The method according to claim 6 wherein said release layer includes a plurality of release blocks, each of said release blocks having a pre-determined  
10 modulus of elasticity.

8. The method according to claim 1, wherein 95 to 100% of said construction layer includes said first interface material and 0 to 5% of said construction layer includes said second interface material.

9. The method according to claim 1, wherein 0 to 5% of said release layer  
15 includes said first interface material and 95 to 100% of said release layer includes said second interface material.

10. The method according to claim 1, wherein said first interface material is a different color than said second interface material.

11. The method according to claim 1, wherein said first interface material is  
20 transparent.

12. The method according to claim 1, wherein said second interface material is transparent.

13. A system for three-dimensional printing of a three-dimensional model, comprising:

at least one printing head, having a plurality of nozzles;

at least first and second dispensers connected to said at least one printing head for dispensing at least first and second interface materials respectively; and

5 control means connected to said at least one printing head for combining at least said first and second interface material in pre-determined proportions to produce layers for forming the three-dimensional model.

14. The system according to claim 13 and further comprising curing means  
10 for optionally curing said layers.

15. The system according to claim 14 wherein said curing means includes:

a first curing means for curing said first interface material for a first period of time and at a first radiation wavelength to obtain a first modulus of elasticity; and

15 a second curing means for curing said second interface material for a second period of time and at a second radiation wavelength to obtain a second modulus of elasticity.

16. The system according to claim 13, wherein said printing head includes first and second printing heads and wherein said first interface material and  
20 second interface material are dispensed from first and second printing heads, respectively.

17. The system according to claim 13 wherein said layers comprise first construction layers and second release layers, said first construction layers and said second release layers having differing proportions of said first and said

second interface materials, respectively, said first construction layers and second release layers having different modulus of elasticity.

18. The system according to claim 13 and further comprising positioning apparatus coupled to said control means for selectively positioning said first and second printing heads by commands from said control means.

19. The system according to claim 13, wherein said layers are photopolymer material curable by the application of any one of a group including ultra-violet radiation, infra red radiation and E-beam.

20. The system according to claim 13, wherein said first interface material is a different color than said second interface material.

21. The system according to claim 13, wherein said first interface material is transparent.

22. The system according to claim 13, wherein said second interface material is transparent.

23. A system for three-dimensional four-color printing of a three-dimensional model, comprising:

at least one printing head, having a plurality of nozzles;

a plurality of dispensers connected to said at least one printing head for dispensing a plurality of interface materials; and

control means connected to said at least one printing head for combining said plurality of interface materials in pre-determined proportions to produce layers having different colors for forming the three-dimensional model.

24. The system according to claim 23, wherein said printing head includes a plurality of printing heads and wherein each of said plurality of interface materials are dispensed from a different one of each of said plurality of printing heads, respectively.
25. The system according to claim 23 and further comprising curing means for optionally curing said layers.
26. The system according to claim 25 wherein said curing means includes:  
at least first curing means for curing at least one of said plurality of interface materials for a first period of time and at a first radiation wavelength to obtain a first modulus of elasticity.
27. The system according to claim 23 wherein said layers have different modulus of elasticity.
28. The system according to claim 23, further comprising a dispenser for dispensing transparent material.
29. The system according to claim 23, wherein said layers are photopolymer material curable by the application of any one of a group including ultra-violet radiation, infra red radiation and E-beam.

## ABSTRACT

A method and a system for three-dimensional printing of a three-dimensional model is provided. The method includes dispensing a first interface material from a printing head, dispensing at least a second interface material from the printing head and combining the first and second interface material in pre-determined proportions to produce layers for forming the three-dimensional model. In one embodiment, the layers forming the construction layers of the model are formed from interface material having a harder modulus of elasticity from the layers forming the release layers, thereby allowing for the forming complex three-dimensional shapes.

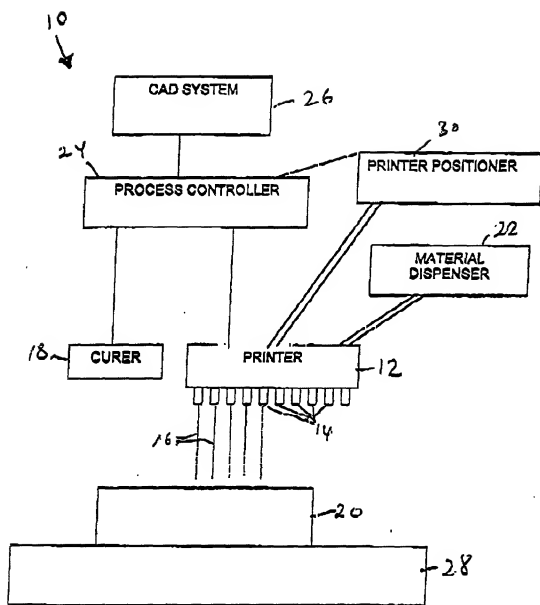


FIG. 1

20:10-11

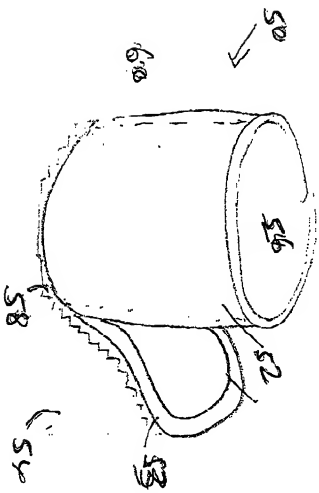
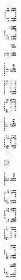


Fig 2

20:10-11



FLG3



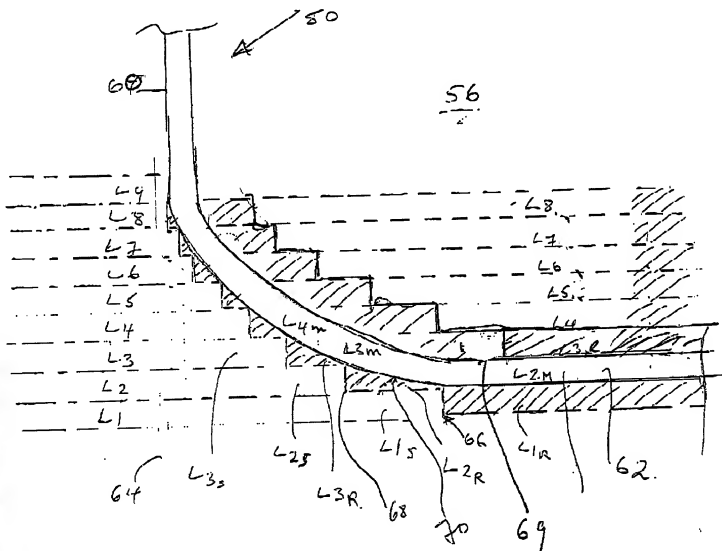


FIG. 4.

in

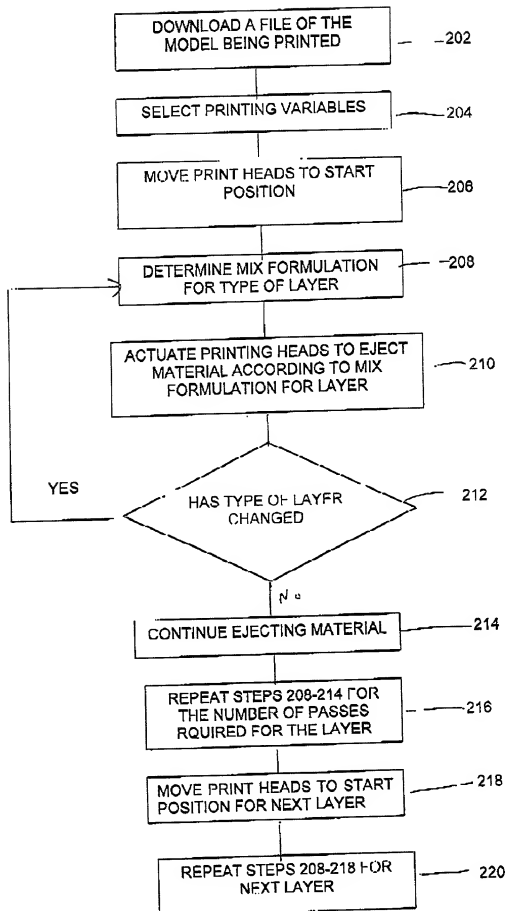


FIG. 5

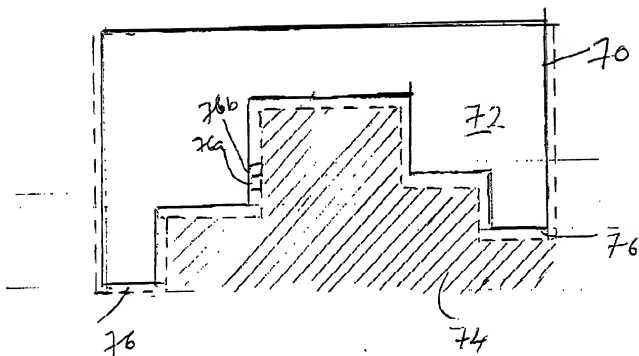


FIG 5A

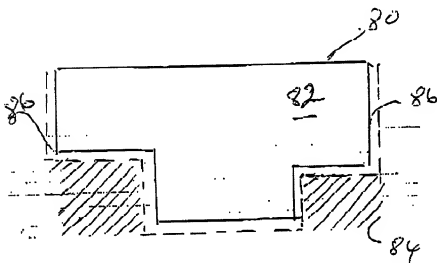


FIG 5B

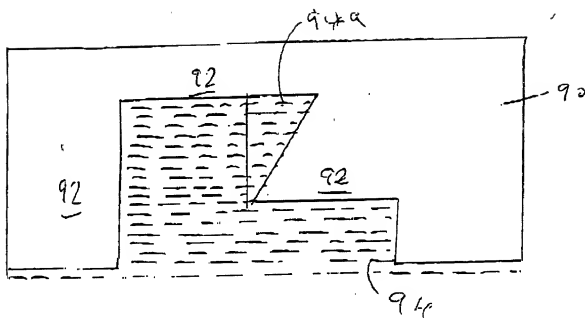


FIG 6C

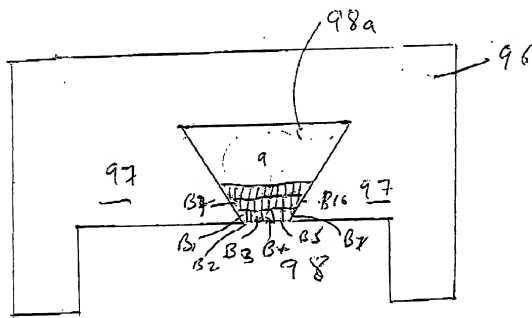


FIG 6D

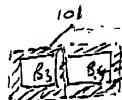


FIG 6E

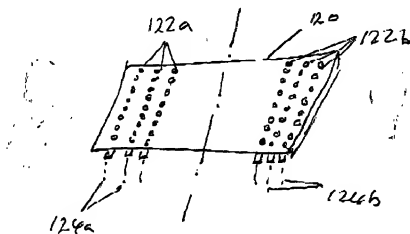


FIG 7.

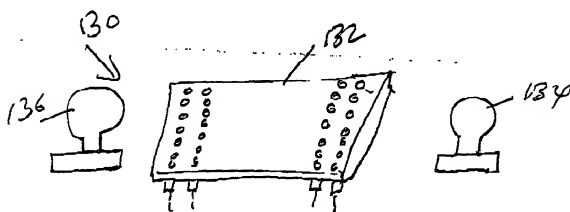


FIG 8

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE  
DECLARATION FOR PATENT APPLICATION  
INVENTOR(S): **GOTHAIT, Hanan**

TITLE : **SYSTEM AND METHOD FOR THREE DIMENSIONAL  
MODEL PRINTING**  
DOCKET NO. : **P-2070-US**

TO THE HONORABLE COMMISSIONER OF PATENTS AND TRADEMARKS:

As a below named inventor, I hereby declare that:

This declaration is of the following type: (check one applicable item below)

- ☒ original  
☐ design  
☐ supplemental

NOTE: If the declaration is for an International Application being filed as a divisional, continuation or continuation-in-part application do not check next item; check appropriate one of last three items.

☐ national stage of PCT

And is a

- ☐ divisional  
☐ continuation  
☐ continuation-in-part (CIP)  
of U.S. Patent Application .

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled **SYSTEM AND METHOD FOR THREE DIMENSIONAL MODEL PRINTING**, the specification of which is attached hereto unless the following is checked:

☐ was filed on as United States Application Number or PCT International Application Number , and was amended on \_\_\_\_\_ (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, § 1.56 (see last page attached hereto).

I hereby claim foreign priority benefits under Title 35, United States Code, § 119(a) (d) or 265(b) of any foreign application(s) for patent or inventor's certificate or 365(a) of any PCT international application which designates at least one country other than the United States of America, listed below and have also identified below any foreign application for patents or inventor's certificate, or of any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Applications:

Priority Claimed:

(Number)	(Country)	(Day/Month, Year Filed)	<input type="checkbox"/> Yes	<input type="checkbox"/> No
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I hereby claim the benefit under 35 U.S.C. 119(e) of any United States provisional application(s) listed below.

(Application No.)	(Filing Date)	(Status - patented, pending, abandoned)
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I hereby claim the benefit under Title 35, United States Code, § 120 of any United States application(s), or 365(c) of any PCT international application designating the United States of America, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, § 1.56 which became available between the filing date of the prior application and the National or PCT international filing date of this application.

(Application No.)	(Filing Date)	(Status - patented, pending, abandoned)
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(Application No.)	(Filing Date)	(Status - patented, pending, abandoned)
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As the inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the U.S. Patent and Trademark Office connected therewith. Name and registration number are listed below.

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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Citizenship : Israeli

Post Office Address: Same

Date: 15 OCT 1993

Signature: X

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Residence : \_\_\_\_\_

Citizenship : \_\_\_\_\_

Post Office Address: \_\_\_\_\_

Date: \_\_\_\_\_

Signature: \_\_\_\_\_



§ 1.56 Duty to disclose information material to patentability.

(a) A patent by its very nature is affected with a public interest. The public interest is best served, and the most effective patent examination occurs when, at the time an application is being examined, the Office is aware of and evaluates the teachings of all information material to patentability. Each individual associated with the filing and prosecution of a patent application has a duty of candor and good faith in dealing with the Office, which includes a duty to disclose to the Office all information known to that individual to be material to patentability as defined in this section. The duty to disclose information exists with respect to each pending claim until the claim is cancelled or withdrawn from consideration, or the application becomes abandoned. Information material to the patentability of a claim that is cancelled or withdrawn from consideration need not be submitted if the information is not material to the patentability of any claim remaining under consideration in the application. There is no duty to submit information which is not material to the patentability of any existing claim. The duty to disclose all information known to be material to patentability is deemed to be satisfied if all information known to be material to patentability of any claim is issued in a patent was cited by the Office or submitted to the Office in the manner prescribed by §§ 1.97(b)-(d) and 1.90. However, no patent will be granted on an application in connection with which fraud on the Office was practiced or attempted or the duty or disclosure was violated through bad faith or intentional misconduct. The Office encourages applicants to carefully examine:

(1) prior art cited in search reports of a foreign patent office in a counterpart application, and

(2) the closest information over which individuals associated with the filing or prosecution of a patent application believe any pending claim patentably defines, to make sure that any material information contained therein is disclosed to the Office.

(b) Under this section, information is material to patentability when it is not cumulative to information already of record or being made of record in the application, and

(1) It establishes, by itself or in combination with other information, a prima facie case of unpatentability of a claim;

or

(2) It refutes, or is inconsistent with, a position the applicant takes, in:

- (i) Opposing an argument of unpatentability relied on by the Office, or
- (ii) Asserting an argument of patentability.

A prima facie case of unpatentability is established when the information compels a conclusion that a claim is unpatentable under the preponderance of evidence, burden-of-proof standard, giving each term in the claim its broadest reasonable construction consistent with the specification, and before any consideration is given to evidence which may be submitted in an attempt to establish a contrary conclusion of patentability.

(c) Individuals associated with the filing or prosecution of a patent application within the meaning of this section are:

- (1) Each inventor named in the application;
  - (2) Each attorney or agent who prepares or prosecutes the application;
- and

(3) Every other person who is substantively involved in the preparation or prosecution of the application and who is associated with the inventor, with the Assignee or with anyone to whom there is an obligation to assign the application.

(d) Individuals other than the attorney, agent or inventor may comply with this section by disclosing information to the attorney, agent, or inventor.